Resistant Pest Management Newsletter

A Biannual Newsletter of the **Center for Integrated Plant Systems (CIPS)** in Cooperation with the **Insecticide Resistance Action Committee (IRAC)** and the **Western Regional Coordinating Committee (WRCC-60)**

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Letter from the Editors

There is little doubt today that resistance is one of the most significant problems facing production of food and fiber, protection of stored products and protection of human health by controlling arthropod borne disease and treatment of human pathogens.

In 1994 a group of concerned resistance workers endeavored to begin a process of educating the world's agricultural extension trainers in resistance management. This decision followed two successful Resistance Management Summer Institutes at Michigan State University where more than 40 trainers from 22 countries had been introduced to the principles of resistance management.

In March of 1995 the first step in this global vision was accomplished with the South American Pest Resistance Management Summer Institute, " Manejo de Resistencia de Plagas, Entermedades y Malezas." Over 40 trainers representing 20 different countries attended. Mike Bush and Saturnino Nunez detail the training sessions on pages 14-15. Our goal is to see other `training the trainers' sessions on every continent by the year 2000. If you can help in this critical process by providing leadership, a location, contacts, organizational support or training resources please contact the editors.

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Resistance Management from around the Globe

Insecticide Resistance in *Helicoverpa armigera* in India

High levels of resistance to DDT in *Helicoverpa armigera* (Hubner) (Lepodoptera: Noctuidae) were recorded in larvae collected from chickpea and pigeonpea at International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru, A.P., between 1986-87. Since organochlorine insecticides like DDT and BHC are cheaper, readily available and traditionally used on food crops by the marginal farmers, the resistance in H. armigera against these insecticides is likely to be widespread. In the absence of baseline susceptibility data, farmers may continue to use these insecticides long after their effectiveness had declined considerably.

In India, poor control of *H. armigera* by synthetic pyrethroids was first recorded on pigeonpea at Lam farm, Guntur, A.P. in 1986 (A. Satyanarayana Reddy, pers. comm.). Poor control was not evident on cotton grown in that area, perhaps because of low populations during that year.

Then in 1987, very poor control of *H. armigera* was recorded on a large scale in the major cotton growing areas of Andhra Pradesh. To tackle this situation, many farmers in this area used synthetic pyrethroids, endosulfan, organophosphate insecticides, and sometimes mixtures at 2-3 days intervals during the critical period. During that particular year, the farmers could not get effective control despite spraying their cotton crop 30 times during the season (compared to the 8-10 recommended sprays R.M. Sawicki unpublished report). Of the total insecticides applied, the synthetic pyrethroids accounted for 50-70% applications. As a result of the poor control of *H. armigera*, the average cotton yields for the major cotton growing districts of Andhra Pradesh, Krishna, Guntur and Prakasam dropped from 436 kg ha -1 in

1986-87 to 168 kg ha -1 in 1987-88. Later in the season, *H. armigera* populations moved to pigeonpea, where again insecticides failed to give effective control. As a result the average yields of pigeonpea for the three districts declined from 392 kg ha -1 in 1986-87 to 214 kg ha -1 in 1987-88.

In November 1987, the poor control of *H. armigera* on pigeonpea was recorded at the ICRISAT Center, Hyderabad, some 250 km northwest of Guntur. By November-December 1987, *H. armigera* were found to be mildly resistant to endosulfan and highly resistant to synthetic pyrethroids (cypermethrin and fenvalerate) at ICRISAT Center, Patancheru, A.P. The level of pyrethroid resistance steadily rose till in March 1988 at ICRISAT. The cypermethrin resistance ratio at ICRISAT Center increased from 40 in early November 1987 to 750 in March 1988. The fenvalerate resistance ratio at ICRISAT Center increased from 120 in early November 1987 to 287 in March 1988. The resistance ratio was expressed as the LD50 of the tested (resistant) strain compared to a control (susceptible) strain. In this case the `Reading" strain, held at Reading University, U.K., where the bioassays were performed, was considered the susceptible strain. Resistance to synthetic pyrethroids was subsequently confirmed as the major cause of crop failures in Andhra Pradesh.

By September 1988, *H. armigera* larvae on millet sorghum and early pigeonpea in the rainy season were again susceptible to synthetic pyrethroids. Tests conducted during November 1988 on *Helicoverpa* from cotton in Prakasam and Juzzuru and for pigeonpea at ICRISAT Center showed that resistance to synthetic pyrethroid had fallen significantly. This decline in the use of synthetic pyrethroids was attributed to the late release of pyrethroid products to farmers in previous years. It was also believed that the source of resistant populations was restricted to cotton belt, approximately 75 km. wide and 200 km. long, comprising Guntur, Prakasam and Krishna districts on the eastern seaboard of Andhra Pradesh.

In the year 1989, high levels of resistance to cypermethrin were recorded in strains from cotton in the cotton growing regions of Guntur, A.P. and Coimbatore, Tamil Nadu and from pigeonpea near Hyderabad. In 1990-91, the survey indicated the pyrethroid resistant populations were present throughout much of Andhra Pradesh. Tolerance to quinalphos had increased slightly in 1990-91, while resistance to Methomyl had increased substantially, particularly in the cotton growing area of Guntur.

In Varanasi area in Uttar Pradesh, pyrethroid resistance was recorded in *H. armigera* larvae collected from early pigeonpea in November 1991 and from chickpea in March 1992 (Nigel Armes, 1992, pers. comm.). The synthetic pyrethroids are rarely used to control *Helicoverpa* in the Varanasi area. This implies that pyrethroid resistance has already moved from south to north. Unless the resistance management strategies appropriate for the region are implemented, the areas affected by the resistant *H. armigera* populations will continue to increase.

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Consequences of Shared Toxins in Strains of *Bacillus thuringiensis* for Resistance in Diamondback Moth

Currently, there are two strains of *Bacillus thuringiensis* (Bt) used commercially on diamondback moth: *B. thuringiensis* subspecies *kurstaki* (Btk) and *B. thuringiensis* subspecies *aizawai* (Bta). Unfortunately, prolonged field use of Btk has led to multiple cases of resistance worldwide for this damaging pest of crucifiers (Tabashnik et al. 1990, Ferre et al. 1991, Hama et al. 1992, Shelton et al. 1993). In those populations examined, the primary mechanism appears to be reduced binding of the CryIA toxins, CryIA(a), and CryIA(c), to its gut membrane binding site with relatively little cross resistance to toxins from other families, e.g. CryIB, CryIC, CryID, CryIE, CryIIA, etc. (Ferre et al. 1991, Tabashnik et al. 1994, Tang et al. 1994). Resistance to Btk spore has also been observed, but so far no mechanism other than reduced CryIA binding has been found to account for the spore resistance (Tang et al. 1994).

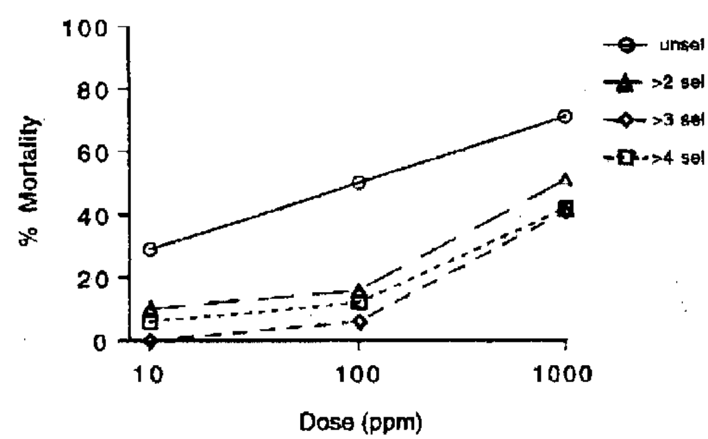
Btk can produce CryIA(a), CryIA(b), CryIA(c), CryIIA and CryIIB protein, and Bta can produce CryIA(a), CryIA(b) or CryIA(c), depending upon isolate, and CryIC and CryID proteins (Koziel et al. 1993). Since resistance to Btk in certain regions of Florida has dramatically reduced its efficacy (Shelton et al. 1993), use of Bta to reduce pest populations of diamondback moth has become more popular. However, the consequences of switching to a different strain of Bt that still expresses a toxin to which resistance has already developed, i.e. CryIA, may negate the resistance management strategy of alternating Bta and Btk products.

From previous collections and spray trails done in 1992, we knew that larvae from Loxahatchee, Florida, were highly resistant to Javelin (Btk) (Shelton et al. 1993), Btk spores, and CryIA (Tang et al. 1994). In 1993, we returned to Loxahatchee and collected about 100 diamondback moth larvae to start a colony for these experiments. Dose-mortality bioassays of the colony in the second generation after it was brought in from the field showed that it was about 1000-fold resistant to Javelin compared to our susceptible laboratory colony, Geneva 1988. Larvae were divided into 4 treatment groups with 2 replications of each and selected for 4 generations with (1) Javelin (Btk, 6.4% AI, Sandoz, Des Plaines, IL), (2) XenTari (Bta, 6.4% AI, Abbott Laboratories, North Chicago, IL), (3) CryIC, or (4) left unselected. Selections were in the 3rd, 4th, 5th, and 6th generations. To monitor the effects of selection on the lines, mortality at three doses were recorded in the 5th, 6th, and 7th generations to the selecting compound, and in the 7th generation for the unselected line. To determine how repeated selection with each of the different compounds affected resistance to CryIA specifically, sensitivity to CryIA(b) was evaluated in the 7th generation for all four lines.

Toxicity assays were prepared from a 10x dilution series. Leaf discs (32mm diameter) were dipped for 10 seconds in three concentrations that best covered the expected range of mortality. Because of limited availability, the highest protoxin concentration tested was 100 g/ml. Mortality in all assays were evaluated after 72 hours at 27 C. Concentrations used in selection assays with Javelin, XenTari, and CryIC ranged from 30 to 200 ppm, 2 to 20 ppm, and 3 to 40 g/ml, respectively. For each selection, mortality at 72 hours ranged from 4-45%, 9-49%, and 10-47%, respectively, and at least 20% of the total number of larvae tested survived to adult ecolsion.

RESULTS AND DISCUSSION The response of the Loxahatchee colony to selection with Javelin was immediate and resistance did not increase any further with the third or fourth selections (Figure 1). Presumably, one or two selections were sufficient to obtain a homozygous or nearly homozygous resistant line indicating that the frequency of Javelin-resistant genes in the field population was relatively high. Even the unselected line, which showed slightly higher mortality to Javelin than the selected lines, was still characterized by high levels of resistance compared to the susceptible Geneva colony (LC50 = 0.3-0.5 ppm).

Figure 1. Response to Javelin Selection



Selection for resistance to XenTari or CryIC was less successful (Figures 2 and 3, respectively) suggesting that genes for resistance to XenTari or CryIC were rare and not represented in the field-collected larvae used to start the laboratory colony. Previous reports, however, have shown that the low levels of resistance to XenTari and CryIC occur in this region of Florida (Shelton et al. 1993, Tang et al. 1994). It is possible that selection in a colony established from several hundred field-collected larvae may have responded differently.

Figure 2. Response to XenTari Selection

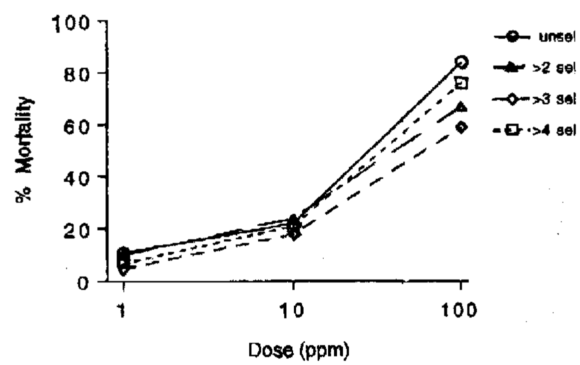
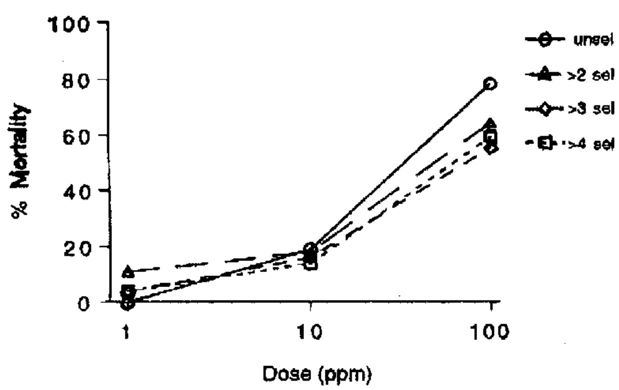


Figure 3. Response to CryIC Selection



The mortality response of each of the lines to CryIA(b) showed that both Javelin- selected and XenTari-selected lines were highly tolerant of this toxin (Table 1). It appeared that there was enough CryIA toxin in the Bta product to select for CryIA-resistant genes even though we were unable to select for resistance to XenTari itself. Thus, use of a Bta product in an area which resistance to Btk has developed may provide control of the population by the Bta spore, CryIC, and/or CryID toxins, but it will do so at some cost to a resistance management strategy. That cost is maintenance of resistance to CryIA toxins contained in both Btk and Bta products. This cost is exacerbated by the fact that resistance to the CryIA toxins can stabilize (Tang et al. 1994) and continued exposure to CryIA in XenTari would eliminate the possibility of even occasional use of Btk products (Table 1). To avoid this dilemma, industry should avoid introducing Bt products with shared toxins that populations have already developed resistance.

Table 1. Mortality Response of Selected Lines to 100 g/ml CryIA (b).

Colony	%Mortality * x se
Unsel	58 6.0a
Jav Sel 4x	4.0 3.0b
XT Sel 4x	4.0 3.0b
CryIC Sel 4x	70 5.0a

* One-way ANOVA, Tukey's, P = 0.05

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Stable Resistance to *Bacillus thuringiensis* in *Plutella xylostell*a

Plutella xylostella is renowned as the only insect species to have evolved significant resistance to Btk from field exposure alone in the Philippines (Ferre et al. 1991), Hawaii (Tabashnik et al. 1990), Japan (Hama et al. 1992), and Florida (Shelton et al. 1993). In previous reports, *P. xylostell*a resistance was unstable reverting back to near susceptible levels within about 10 generations (Hama et al. 1992, Tabashnik et al. 1994), and resistance was inherited as an autosomal recessive or incompletely recessive trait controlled primarily by one or few loci (Hama et al. 1992, Tabashnik et al. 1992). In contrast to these studies, we observed Btk resistance in one of our Florida populations of *P. xylostella* to be very stable, maintaining high levels of resistance even in the absence of further selection. This presents tremendous problems for developing resistance management strategies.

MATERIALS AND METHODS

INSECTS. Origins of the resistant Loxahachee (Florida, collected 1992) and susceptible Geneva (New York, 1988) colonies have been described (Shelton et al. 1993, Shelton et al. 1991). Geneva larvae, reared as before (Shelton et al. 1991) were used in generations 94-106. Similar levels of susceptibility as the Geneva larvae have also been found in the field (Shelton et al. 1993). Loxahachee larvae were maintained on rape in the greenhouse at 26-33C, 16:8 h light:dark photoperiod, and 20-80% relative humidity.

TOXICITY BIOASSAYS. Javelin mortality data for the Loxahachee and Geneva colonies were generated using leaf dip bioassay (Shelton et al. 1993). Colonies were tested concurrently and replicated on 2 different days. On each day, 6-8 concentrations were prepared including a control with 5 leaves per concentration and 5 larvae per leaf. Mortality was determined at 96h.

DATA ANALYSIS. Bioassay data was analyzed with logit models using the POLO program (Russel et al. 1977). The 2 goodness of fit test was used to determine how well the backcross data fit a monogenic model of inheritance (Tabashnik 1991).

RESULTS

STABILITY OF RESISTANCE. After the Loxahachee colony was brought in from the field, resistance to Javelin was monitored over time. A plot of the Javelin resistance ratio showed that the Loxahachee colony was extremely resistant to Btk (resistance ratio > 1500), and that in the absence of selection such high levels of resistance were unstable, declining significantly within 3 generations (Figure 1). Resistance remained relatively stable over the next 7 generations at about 150- to 300- fold.

Selection of the Loxahachee colony in the 4th generation by exposing over one thousand 2nd instar larvae to cabbage leaves dipped 10 sec in 316 ppm Javelin, for 96h resulted in 57% mortality, and 114 adults survived to continue the colony. The selection resulted in a resurgence of the resistance ratio (> 1000-fold) followed by a gradual decline to about 300-fold resistance (Figure 1). By the 19th generation without further selection, the LC50 still proved to be 166-fold higher compared to the Geneva colony.

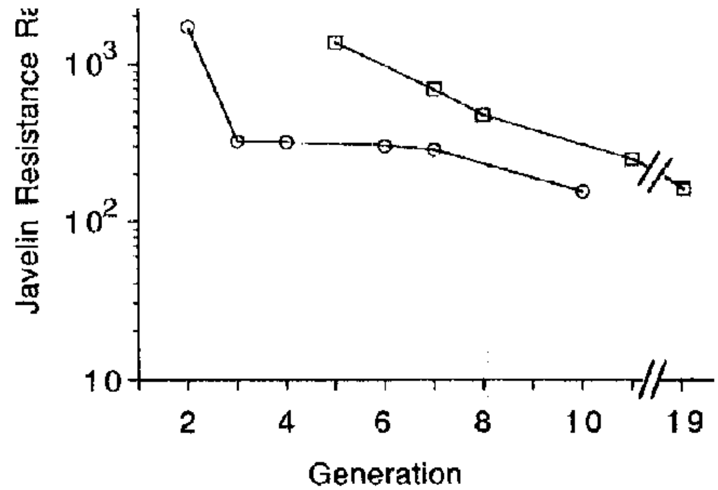

Figure 1. Changes in the Javelin resistance ratio (=LC50 of Loxahatchee colony/LC50 of Geneva colony) in the absence or presence of a single selection at 316 ppm in the 4th generation. LC50 values were estimated from POLO probit analysis of mortality data from 2nd instar larvae of P. xylostella. Data from the 2nd generation was also published in Shelton et al. (1993).

GENETIC BASIS OF RESISTANCE. The proximity of the dose-mortality regression lines of the Geneva and F1 larvae indicated that resistance was an incompletely recessive trait (Figure 2). To test the hypothesis that resistance was due to a single locus, dose-mortality responses of the backcross progeny were plotted and analyzed using the 2 goodness of fit test for monogenic inheritance (Figure 2). Of the 9 doses evaluated, mortality deviated from expected only at 100 ppm (P=0.006, df=1), indicating that a single gene model provided a good fit to the data.

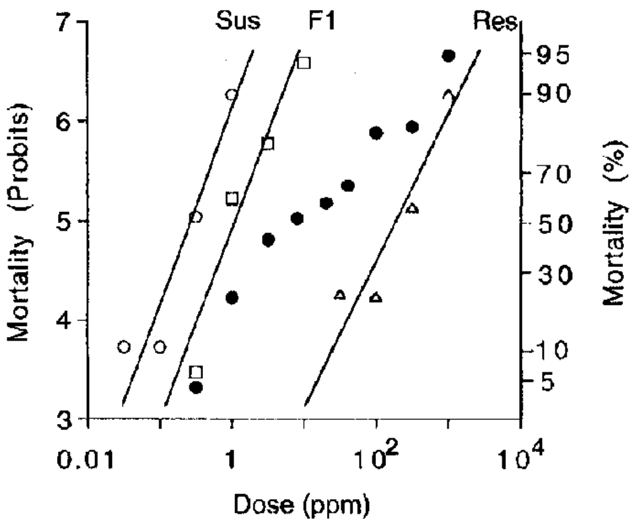

Figure 2. Mortality responses to Javelin of susceptible (), resistant (), F1 (), and backcross larvae (). Larvae were from the following colonies or crosses: susceptible = Geneva, F1 = Geneva x Loxahatchee, resistant = Loxahatchee, and backcross = F1 x Loxahatchee. Regression lines were estimated from POLO probit analysis. N=60 for each backcross data point.

DISCUSSION In this investigation of resistance to Btk in *P. xylostella*, for the first time we show that resistance did not revert to susceptibility in the absence of selection. Our population may be typical of Bt resistance developed in the field, and even at levels of stable resistance (150- to 300-fold) such populations have been shown to exhibit control failures in the field (Shelton et al. 1993) and to transgenic plants (Metz et al. 1994). This will be problematic for resistance management.

Changes in the Javelin resistance ratio of our Floridian population of *P. xylostella* proved to be biphasic, i.e. initially high resistance ratios declined followed by a plateau stabilizing at about 300-fold. This was unlike resistant populations from Japan and Hawaii that displayed complete reversion (within 10-fold) to susceptibility (Hama et al. 1992, Tabashnik et al. 1994). Thus, although our strain may carry some factors (minor genes) that are lost quickly, our population was probably not characterized by the fitness costs that caused nearly complete reversion in the Hawaiian population (Groeters et al. 1994, Tabashnik et al. 1994). The inheritance of resistance, however, appears to be similar. In our population as well as in the Japanese (Hama et al. 1992) and Hawaiian (Tabashnik et al. 1992) populations, resistance was completely or in completely recessive and apparently due to one gene. The reasons for differences in fitness and dominance await further investigation, but given the similarities in mechanisms, suggests that there could be multiple resistance alleles even if the same gene is involved.

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Resistance of Large Apple Bagmoth to Three Insecticides in China

In China, the large apple bagmoth, *Crytothelea variegata* Hampson, is one of the important forestry pests. Control of this pest has become more and more difficult despite increased chemical applications. We measured resistance to three insecticides (Deltamethin, Monocrotophos, and Omethoate) in the large apple bagmoth from 1992 to 1994.

Bagmoths collected from the field were brought to the laboratory and assayed with the topical application procedure recommended by FAO (1980) (Table 1). Mortality was assessed 48 hours after the treatment.

Table 1. The value of Large apple bagmoth resistance levels.

Insecticide Treatment	Year	Y= a+bx (g/g)	LD50	R	Ratio*
Deltamethrin	1992	11.0799+1.4538x	6.57E-05	0.9894	--
	1993	10.0228+1.2984x	1.35E-04	0.9996	2.1
	1994	8.6859+1.4665x	3.07E-03	0.9967	46.6
Monocrotophos	1992	10.1057+1.4493x	3.00E+00	0.9975	--
	1993	9.4519+1.4057x	6.81E-04	0.9981	2.3
	1994	8.8531+1.6549x	4.69E-03	0.997	15.7
Omethoate	1992	11.8907+1.6586x	7.01E-05	0.9789	--
	1993	10.5133+1.5790x	3.22E-04	0.9881	4.6
	1994	9.0301+1.5130x	2.17E-03	0.9924	31

* Ratio = LD50/LD50 (1992)

RESULTS and CONCLUSION Resistance levels to these insecticides distinctly increased paralleling the increased usage of these chemicals in the field. (Table 1). The efficacy and level of control from each of the three pesticides has declined between 1992 - 1994. Deltamethrin and Omethoate may no longer be effective in controlling the large apple bagmoth.

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Resistance Management of Cotton Bollworm With Mixtures of Insecticides

In the People's Republic of China, most cotton farmers already use mixtures or rotations of pesticides extensively in cotton bollworm resistance management. Although mixtures and rotations of pesticides are promoted for managing resistance, which mixtures or rotations to use has not been evaluated. We considered the use of 4 or 5 insecticide products with no cross-resistance as mixtures and as rotation of mixtures. This strategy may decrease or delay the continued development of resistance. With this strategy, we managed resistant populations in the Liaocheng cotton area, Shandong Province, China, between 1990 to 1993.

We collected cotton bollworm, *Helicoverpa (Heliothis) armigera* (Hubner) from the field and selected with Deltamethrin for 95 generations to obtain a highly resistance colony. Three mixtures of insecticides were selected: MCJ (Deltamethrin, Methomyl and Phoxim), KLJ (Thiodan, Deltamethrin and Phoxim) and MLG (Deltamethrin, Methomyl and Parathion).

The first mixture (MCJ) was applied to the resistant colony of cotton bollworm for 10 generations, then the second mixture (KLJ) was applied for 10 generations, and then the third mixture (MLG) was applied for an additional 10 generations. Finally, the first mixture (MCJ) was applied for another 10 generations. Bollworm response to Deltamethrin was assessed every 10 generations by a topical application assay recommended by FAO (1980) and bollworm response to each mixture was assessed before and after the sequence was applied to the colony. Mortality response was determined 48 hours after exposure.

RESULTS Table 1 shows that after 10 generations of selection pressure resistance increased 1.8 fold for MCJ, 1.4 fold for KLJ, 0.85 fold for MLG and 1.4 fold for the second MCJ application. Meanwhile, resistance levels for Deltamethrin continually decreased 35.2 fold by the conclusion of the study.

Table 1. Study on the use of mixtures in cotton bollworm resistance management.

Mixtures, variety of insecticides	LD50 Baseline (ug/g)	1-11 gener. after using MCJ 10 times		12-22 gener. after using MCJ 10 times		23-33 gener. after using MCJ 10 times		34-44 gener. after using MCJ 10 times	
		LD50	Ratio	LD5o	Ratio	LD50	Ratio	LD50	Ratio
MCJ	1.8818	3.3872	1.8	--	--	--	--	2.635	1.4
KLJ	0.8276	--	--	1.1586	1.4	--	--	--	--
MLG	0.4892	--	--	--	--	0.4258	0.85	--	--
Deltamethrin	1.0536	0.0976	-10.9	0.0585	18	0.0357	-29.5	0.0299	35.2

Notes: gener. = generation. Ratio = LD50/LD50 baseline LD50 (g/g)

CONCLUSION In this study, multiple resistance did not occur when we rotated mixtures of pesticides. This strategy can delay resistance development. The use of rotation of pesticide mixtures may provide a most effective strategy to increasing the life of a single pesticide. The use of mixtures increased the effectiveness of Deltamethrin to control bollworm by reducing the level of resistance.

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Pyrethroid Resistance Management in H*elicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in Cote d'Ivoire

Helicoverpa armigera (Lepidopotera: Noctuidae) has developed resistance to chemical insecticides in many countries.

The susceptibility of this polyphagous pest to pyrethroids has been monitored at the Institut des Savanes research station since 1985. The results for 1985-1992 did not reveal a change in pest sensitivity tending towards resistance.

In 1992, tests were carried out on *H. armigera* during the cropping season on four of its main host plants in Cote d'Ivoire: cotton, tomato, okra and maize. Tests were also performed on larvae collected from sprayed plots of cotton. Different lethal doses indicated pest susceptibility.

Several methods of pesticide application recommended for the detection of resistance in *H. armigera* in the laboratory were compared. Topical application was more accurate and more reproducible than leaf residue or adult vial test. Another study showed that the use of a "diagnostic dose" is a good complement in appraisal of the resistance factor.

In addition, the Bouake population is subjected to various selection pressure systems so that the best strategy for prevention of resistance can be chosen. Insecticide combinations seem better than insecticide alternations. Small doses at a high frequency seem better than large doses at a low frequency. However, the differences observed in the Bouake population are small probably because of the low frequency of resistant larvae in the sample subjected to selection pressure.

New experiments are in progress on a population in which resistant larvae were introduced. Furthermore conclusive confirm the advantages of mixing insecticides.

The pyrethroid-ogranophosphorus mixtures used since 1983 may also partially explain the preservation of the susceptibility of *H. armigera* to pyrethroids in Cote d'Ivoire.

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Pyrethroid Resistance in H*elicoverpa armigera* in Nepal

Entomologists at Lumle Agricultural Research Centre, Pokhara, Gandaki Anchal, Nepal, noticed that failures to control the cotton bollworm, *Helicoverpa armigera* on field crops have become increasingly common since the early 1990's. In April 1993 and May 1994, *H. armigera* larvae were collected from tomato crops in the Pokhara region where maize, wheat, pulses and vegetables are major crops susceptible to *H. armigera* attack. Pupae were sent to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India. Resulting F1 generation larvae were assayed for resistance by topically applying serial (30-40 mg) concentrations of pyrethroid (cypermethrin, fenvalerate), endosulfan, organophosphate (quinalphos, monocrotophos) and carbamate (methomyl) insecticides to individual larvae derived from the 1993 and 1994 Pokhara field strains. Bioassays were conducted at 25 2C and data analyzed using standard log dose probit (ldp) statistics. Comparisons were made against the ldp responses of an insecticide susceptible strain of *H. armigera* maintained in the laboratory at ICRISAT.

The data show that *H. armigera* strains from Pokhara are moderately resistant to pyrethroids (12-56 fold). The cypermethrin results indicate that resistance had increased between 1993 and 1994. Pre-treatment with the synergist piperonyl butoxide (PBO) reduced resistance levels close to the susceptible strain response, indicating that pyrethroid resistance is most likely due to metabolic detoxification.

Tolerance to endosulfan (2-3 fold) and methomyl (2 fold) was recorded, but there was no indication of resistance to phosphate (monocrotophos) or phosphorothionate (quinalphos) organophosphate insecticides.

The fact that *H. armigera* has been confirmed to be resistant to pyrethroids in the middle mountains region of Nepal where insecticides are not used excessively, should be considered with concern. Insecticides are more frequently used on cotton and pulses grown on the lower lying alluvial soils of the Tarai region, so it is likely that *H. armigera* populations there will have even higher levels of pyrethroid resistance. As Pokhara is only 340 km NNW of Varanasi in Uttar Pradesh, India, where pyrethroid resistance was confirmed in 1991 (Armes, unpubl.), pyrethroid resistance in *H. armigera* populations in Nepal may have arisen because of moth migration from India.

Also of concern is the fact that the Pokhara strain recorded tolerance, albeit at quite low levels, to endosulfan and methomyl. Even low level endosulfan resistance has resulted in field control problems in Australia and India in the past. At the present time organophosphate resistance does not appears to be present.

Our results suggest that the increasing reports of difficulties in controlling *H. armigera* with insecticides in Nepal may in part be attributed to pyrethroid resistance and tolerance to endosulfan and carbamates. We plan to collect and bioassay *H. armigera* strains from a wider geographic range during 1995-96.

Table 1

Table 1. Toxicity of topically applied pyrethroid, endosulfan, organophosphate and carbamate insecticides to 30-40mg *H. armigera* larvae from Nepal

Insecticide/Strain	LD_{50} (ug/larva)	Slope	Rf[a]	SR[b]
Cypermethrin				
Lab Susceptible	0.007	2.4	---	---
Pokhara 1993	0.082	1.3	12	---
Pokhara 1994	0.390	2.3	56	---
Cypermethrin + PBO				
Lab Susceptible	0.007	2.3	---	1
Pokhara 1993	0.013	1.9	2	6
Pokhara 1994	0.073	2.0	10	5
Fenvalerate				
Lab Susceptible	0.019	2.0	---	---
Pokhara 1994	1.000	1.1	53	---
Fenvalerate + PBO				
Lab Susceptible	0.018	2.2	---	1
Pokhara 1994	0.032	1.5	2	31
Endosulfan				
Lab Susceptible	0.640	3.0	---	---
Pokhara 1993	1.000	2.0	2	---
Pokhara 1994	1.800	1.9	3	---
Quinalphos				
Lab Susceptible	0.056	2.6	11	---
Pokhara 1993	0.063	4.4	1	---
Pokhara 1994	0.047	3.3	0.8	---
Monocrotophos				
Lab Susceptible	0.870	2.1	---	---
Pokhara 1993	0.710	1.4	0.8	---
Pokhara 1994	0.370	1.8	0.4	---
Methomyl				
Lab Susceptible	0.130	2.0	---	---
Pokhara 1994	0.280	1.5	2	---

RF[a] (resistance factor) = LD50 Pokhara strain/LD50 Lab. susceptible strain

SR[b] (synergist ratio) = LD50 without PBO/ LD50 with PBO pretreatment

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Resistant B-Biotype of *Bemisia tabaci* Detected in Australia

B-Type *Bemisia tabaci* was detected in Australia for the first time in October 1994. The insects were identified by esterase isoenzyme patterns. The initial identifications were made in *B. tabaci* collected from a rockmelon crop in Darwin, Northern Territory and at Tamworth, New South Wales plant nursery.

The distinctive isoenzyme profile was consistent with those found in contemporary B-type populations from other geographic regions. Furthermore, the insects induced typical silverleaf symptoms in Curcubita spp. Preliminary evaluation of the in vitro effects of organophosphorous (OP) and carbamate insecticides showed a high degree of insensitivity of the enzyme. The levels of insensitivity detected are sufficiently high to seriously threaten any effective role for OP's and carbamates in a chemical control program in Australia.

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Bioassays With Recommended Field Concentrations of Several Insecticides for Resistance Monitoring in *Plutella xylostella*

The diamondback moth (DBM), *Plutella xylostella* has the potential to develop resistance to almost any insecticide if applied intensively. It is also the only species where resistance to *Bacillus thuringiensis* (Bt) has been documented in field populations (Tabashink 1994). Resistance monitoring is essential to resistance management programs and should be more important for DBM because of its resistance potential. Zhao and Grafius (1993) suggested that both the LC90 (or LC99) for susceptible DMB strain and the recommended field concentration of insecticide could be used to detect resistance at low levels and to help choose insecticides for the control of DMB strains with higher resistance levels. Further studies were carried out to test this hypothesis in P.R. China.

The acylureas chlorfluzuron was the most effective insecticide available for the control of DBM in P.R. China in the late 1980's. It was introduced for commercial application in 1989. The larvae immersion bioassay (Zhao et al. 1994) was used for on-farm resistance monitoring in 1989-1993 with two methods: the diagnostic test using recommended field concentration (25 ppm) of chlorfluazuron as the discriminating concentration, and the dose/response test to calculate the resistance ratios (RRs) based on LC50. The field efficacy in 5 days after treatment (DAT) decreased from 96.7% in June of 1993 to 82.9% in September of 1993. The resistance frequency increased from 5.4% in June to 23.1% in October of 1992 and from 24.1% in June to 62.5% in September of 1993, indicating the evident resistance development from June to September or October at the peak stage of DBM with most intensive spraying. Whereas the RRs in June and September of 1993 were similar (Table 1). So the results by diagnostic tests under the recommended field concentration was proved to be more compatible with the change of field efficacy than the RRs tests.

Table 1. Monitoring of chlorfluazuron resistance in *P. xylostella* by diagnostic (%) and dose/response (RR) tests in Shanghai.

Month & Year	Resistance frequency (%)	RR
August-89	0	1.00 (LC50 = 0.70)
August-90	0	1.75
August-91	3.7	2.42
June-92	5.4	2.62
October-92	23.1	2.62
June-93	24.1	2.69
September-93	62.5	3.35

The recommended field concentrations of nine classes of insecticides with different mode actions were also used in bioassays and field efficacy tests in 1993-1994 in Shanghai. The mortalities in bioassays were compatible with the field efficacies of each class of insecticide (Table 2). These results are valuable for the choice of insecticides for DBM control and this approach is potentially useful for other insect pests.

Table 2. Comparison of mortality in bioassay and field efficacy under recommended field concentrations of nine insecticides.

Insecticide	Concentration (ppm)	Bioassay		Field trial	
		DAT	% Mortality	DAT	% Efficacy
Fenvalerate	400	1	21.2	3	21.4
Methomyl	480	1	32.5	3	61.5
Chlorfluazuron	25	4	75.9	5	96.7
Dimehypo	360	2	80	3	81.2
Bt	17	2	75.6	3	69.4
Abamectin	12	3	98.4	3	98.5
Fipronil	20	1	100	3	100
Diafenthiuron	600	3	100	3	100
AC303630	40	2	100	3	100

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Resistance Management Reviews

US EPA's Role in Resistance Management

At least since the early 1980's, various individuals and groups have urged the US Environmental Protection Agency (EPA) to take a more active role in resistance management. As outlined by Mike Dover and Brian Croft ("Getting Tough: Public Policy and the Management of Pesticide Resistance, published in 1984 by World Resources Institute), the EPA has a profound (and not altogether beneficial) impact on resistance management by virtue of its current regulations and could significantly improve resistance management with the adoption of additional or alternative policies. The merits of these proposals have been debated at length at various meetings, including by a committee of the National Academy of Sciences ("Pesticide Resistance: Strategies and Tactics for Management", 1986) and at various meetings of professional societies, including the Entomological Society of America. Recently, various public interest groups have added their voices to the chorus, urging that the EPA refuse to approve Bt-transgenic insecticidal crops until the "EPA has in place workable, enforceable resistance management strategies".

There is insufficient space here to review these debates, but it seems clear that the EPA is reluctant to use regulation to help delay resistance to pesticides. In the EPA's defense, it may not have to do so. EPA has made some modest Proactive efforts in avoiding resistance, such as requesting resistance management statements from some companies developing transgenic plants and more traditional pesticides. Nonetheless, in the absence of any efforts to enforce or facilitate the adoption of resistance management plans, such documents clearly have little more than public relations or educational value.

My main point in this editorial is to suggest how we might encourage the EPA to be a more effective partner in managing resistance without requiring any expansion of EPA's legal mandates or any significant increase in the work load of its already overburdened staff. I base my suggestions on recent experiences with both transgenic crops and imidacloprid, a novel insecticide with major applications in control of whiteflies and the Colorado potato beetle, pests which are notorious for resistance evolution.

Knowledge is power, or at least influence. In the case of imidacloprid, the insecticide can be used for Colorado potato beetle (CPB) control either as a soil application or a foliar spray. The soil application (tradename "Admire") has a half-life of some 50 days (controlling the entire first generation of CPB), whereas foliar sprays (tradename "Provado") have a half-life of 1-2 days. Due to the greater persistence of the soil applications, 1-3 applications of Provado would be preferable to a soil application of Admire in a resistance management program. Several potato entomologists urged both EPA and the US registrant (Miles Inc.) to support labeling of both Admire and Provado to assure local flexibility in resistance management efforts. Unfortunately, many of us were unaware of a lack of residue data that forced EPA to require a 12 month "plant back" restriction for both Admire and Provado. Currently, this essentially means that the land on which an imidacloprid application has been made to potatoes cannot be rotated to another crop for at least 12 months. Crop rotation is very important in potato production, with important agronomic advantages (including disease suppression) in addition to being a most effective tactic for managing resistance in CPB (the adults must hunt to find a new potato field, which slows population growth and reduces dependence on insecticides). Since Admire is applied at planting (often at least 12 months before a rotational crop would be planted), this is not a limitation to the soil applications, but is a severe impediment to the use of Provado, which would be applied later in the season. In sum, the lack of adequate residue data has severely impeded efforts to prevent or delay resistance to a valuable new insecticide. A further complication is that growers have now made the investment in new equipment to apply Admire, which will inhibit their willingness to switch back Provado when and if the residue questions are resolved.

While entomologists were unaware of residue data gaps and their implications, the appropriate EPA officials were in turn apparently unaware of the importance of crop rotation in potato production and pest management. Thus, while the data gaps might have been raised by the EPA and addressed in a timely fashion by the registrants, we are now faced with a considerable obstacle to resistance management, the plant-back period. It would be naive to think that companies will always be willing to generate the data necessary to avoid problems such as this. However, it must certainly be true that improved communication between resistance managers and the EPA could help to avoid such problems among parties of good intentions.

I encourage readers to write to the EPA at the earliest opportunity with any serious concerns about resistance management for new products. Each individual, in consultation with colleagues, will have to decide whether his or her concerns are truly serious, remembering that EPA staff are already overburdened, and that too much letter writing will only diminish attention to the most serious problems. To make sure that letters get distributed to all relevant parties in the agency, send letters to management. Currently, the appropriate officials are two Division Directors of the office of Pesticide Programs: Mr. Stephen Johnson (Registration Division, 7505C) and Dr. Janet Anderson (Biopesticides and Pollution Prevention, 7501W), both at EPA, 401 M Street, SW, Washington, DC 20460. If you know the specific product manager at EPA, send him or her a copy.

In general, more companies should submit resistance management statements to the EPA about their new products. Even as I type this, I can hear the collective groan from pesticide companies around the world, who have often voiced their opinion that this is not something in which the EPA should get involved. However, before rushing to judgment, I think companies would do well to study the approach that has been taken by Monsanto in considering resistance management for its Bt-transgenic crops. During a Scientific Advisory Panel (SAP) meeting at EPA on March 1, 1995, Monsanto was praised by both contributors from the public and SAP members for the thoroughness of its resistance management proposals. To develop these proposals, Monsanto has not spent vast sums on research, but relied extensively on meetings with researchers in the pubic sector and some modest support of their research. I am confident that if asked, the participating Monsanto personnel would agree that they have learned a lot of useful information in the process. I believe that I can speak for other University and USDA scientists in noting that we learned a lot from Monsanto. My point here is not mutual "back-patting", but that this process can clearly be much less onerous than industry has feared. In many if not most cases, resistance management plans for other systems can be developed at far less expense. The strategies in resistance management are often fairly obvious; the problem is more often in implementation, which could be facilitated by better communication between government and industry.

In the long term, the EPA should work toward offering encouragement and inducements to companies to help them manage resistance, and to reward those who do (such as faster processing of registrations which include label restrictions to promote resistance management). In the meantime, however, improved efforts at making the EPA aware of resistance management issues empowers them to help us in the field. In extensive discussions and correspondence over the last few months, I have found the EPA to be willing to help; it remains up to us to try to educate the EPA about what is needed. The EPA will not be able to solve all of our implementation problems in resistance management, but I am convinced that the EPA can be helpful in at least some instances.

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Resistance Management News

Biocontrol

The International Center for the Biological Control of Pests and Pathogens

In May 1993, the Minister of Agriculture of the government of Peru authorized the creation of "BIOCONTROL", the International Center for the Biological Control of Pests and Pathogens in Lima, Peru under the sponsorship of Oklahoma State University. Statutes of BIOCONTROL were approved in July of the same year and on October 31, 1994 land and building facilities were assigned to BIOCONTROL for carrying out its activities. BIOCONTROL is an autonomous and nonprofit international scientific organization headquartered in Lima, Peru. BIOCONTROL will be working toward increasing yield capability and production efficiency of food and fiber crops by developing and transferring technologies which promote the biological control of pest and pathogens, natural products, and products of biotechnologies to lower the cost of production, achieve a sustainable agriculture, conserve natural resources and preserve the environment. Over 30 projects concerning various aspects of biotechnology and biological control of different important food and fiber crops have been developed and are ready for implementation. BIOCONTROL welcomes collaborative association with different scientists, organizations and universities. For more information please contact the author.

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Biocontrol Publication

International Center for the Biological Control of Pests and Pathogens "BIOCONTROL" proudly announces the production of the world's first bilingual (English & Spanish) publication, Biocontrol, which is dedicated entirely to reporting the latest advances in biotechnology and biological control of pests and pathogens to scientists, policy makers, administrators, farmers, agriculture producers and biological control practitioners. Through its new international publication, BIOCONTROL is closing the communication gap in the dissemination of information and will be promoting the multidisciplinary efforts in biological control. There will be no page charges for the publishing in this peer-reviewed international publication. Biocontrol will be published quarterly and has a distribution of 3000 copies per issue. It is printed by the Allen Press Inc. and distributed from Lawrence, Kansas. There will be a $25.00 individual and $125.00 subscription fee per year. Send checks drawn on a U.S. bank to: BIOCONTROL, Apartado 18-1057, Lima 18, Peru. South America.

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Herbicide Resistance Workshop

The proceedings of the Herbicide Resistance Workshop held in Edmonton (Alberta, Canada), on the 9-10 December 1993, have been published in a supplement to Volume 75 of Phytoprotection. Experts in the field of resistance have contributed the following papers:

- Herbicides resistance in the Canadian prairie provinces: Five years after the fact. I.N. Morrison & M.D. Devine.
- Mechanisms of cross and multiple resistance in Alopecrus myosuroides and Lolium rigidum. L.M. Hall, F.J. Tardif & S.B. Powles.
- Population genetics and the evolution of herbicide resistance in weeds. M.J. Jasieniuk & B.D. Maxwell.
- Relative fitness of herbicide-resistant and susceptible biotypes of weeds. S.I. Warwick & L.D. Black.
- Principles of insecticide resistance management. G.P. Georghiou.
- Integrated weed management strategies for delaying herbicide resistance in wild oats. D.C. Thill, J.T. O'Donovan & C.A. Mallory-Smith
- Herbicide resistant crops: a weed scientist's perspective. W.E. dyer
- Herbicide resistant crops in resistant weed management: An industrial perspective. D. Shaner. Identification and documentation of herbicide resistance. I.M. Heap.
- Resistant pests: a producer's perspective. G. McPhee.
- An extension program for ACCase inhibitor resistance in Manitoba: A case study. M. Goodwin.

This 108-page supplement also includes an exhaustive subject index, listing weeds, crops, insects, herbicide families, enzymes, and broader terms such as biotype differentiation, cross-resistance, and herbicide compartmentation. The proceeds are available for $15.00 US in the United States and other countries ($15.00 CAN in Canada). to receive your copy, please send your name and address with a money order or check to the order of Phytoprotection, to: Phytoprotection, Agriculture and Agri-food Canada Research Station, 430 Gouin Blvd., Saint-Jean-sur-Richelieu, Quebec, Canada J3B 3E6.

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May, R. M. "Agriculture - Resisting Resistance." Nature 361, no. 6413 (18 February 1993): 593-594.

Rohrer, S. P., E. T. Birzin, C. H. Eary, J. M. Schaeffer, and W. L. Shoop. "Ivermectin binding sites in sensitive and resistant Haemonchus contortus ." Journal of Parasitology 80, no. 3 (June 1994): 493-497.

Sutherland, I. A., and D. L. Lee. "Acetylcholinesterase in Infective-Stage Larvae of Haemonchus contortus, Ostertagia circumcincta and Trichostrongylus colubriformis Resistant and Susceptible to Benzimidazole Anthelmintics." Parasitology 107, no. Part 5 (December 1993): 553-557.

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Symposia

Dates to Remember:

June 18-23, 1995 --
Molecular Genetics and Ecology of Pesticide Resistance, Montana, USA: American Chemical Society, Division of Agrochemicals Special Conference VI, 1155 Sixteenth Street, NW, Washington DC 20036, USA. Tel +1 (202) 872-6286; Fax: +1 (202) 872-6128.

July 2-7, 1995 --
XIII International Plant Protection Congress, The Hague, The Netherlands: XIII International Plant Protection Congress, c/o Holland Organizing Centre, Lange Voorhout 16, 2514 EE The Hague, The Netherlands. Tel. +31 70 365 78 50; Fax: +31 70 361 48 46.

July 5-14, 1995 --
Third Annual Summer Institute on Global Pest Resistance Management, Michigan State University, USA: Summer Institute, Michigan State University, B-11 Pesticide Research Center, East Lansing, Michigan 48824-1311, USA. Tel +1 (517) 355-1768; Fax: +1 (517) 353-5598, e-mail: bushm@pilot.msu.edu (Dr. Michael R. Bush, Training Manager)

South American Workshop on Global Pest Resistance Management (March 27 to April 1, 1995)

We are pleased to announce that the regional workshop on pest resistance management held in Las Brujas, Uruguay was a huge success. "Manejo de Resistencia de Plagas, Entermedades y Malezas" was hosted by the Instituto Nacional de Investigacion Agropecuaria (INIA) in cooperation with Michigan State University from March 27 to April 1, 1995. Funding for this workshop was contributed by Consejo Nacional de Investigaciones Cientificas y Tecnicas (CONICYT) and Programa Cooperativo de Investigacion Agricola del Cono Sur (IICA-PROCURSUR). Additional funding was provided by BASF, Proquimur, Maccio y Cia, Cibeles, Zeneca, Conaprole, Gualequay S.A. (Talar), Bodegas y Vinedos "Santa Rosa", and Vinos Finos- Juan Carrau. Thank you for your support. The workshop was attended by 45 entomologists, plant pathologists, horticulturists and weed scientists from Argentina, Bolivia, Brazil, Chile, Nicaragua, Paraguay, Peru, Dominican Republic, Venezuela, and Uruguay.

Throughout the South American workshop, participants and instructors discussed in convincing fashion the threat that pest resistance posses to global agriculture. There are relatively few documented cases of resistance in South America compared to North America. Nevertheless, we implore South American researchers, teachers and crop managers to take this threat seriously. We encourage workshop participants to further disseminate information on resistance and resistance management to their respective countries. Workshop instructors from Michigan State University and Cornell University, as well as participants, developed a better appreciation of the difficulties and complexities of managing resistance once it emerges in the form of pest control failures. It was recommended that researchers accumulate baseline data on the susceptibility of South American pests to pesticides for future references. Everyone agreed that the best strategy for resistance management was to avoid resistance development by diversifying our pest control tactics (both chemical and non-chemical) to reduce further selection pressure on a single control tactic. Pesticides and other control tactics (crop rotation, mating disruption, cultural control, biological control, etc.) are valuable and perhaps nonrenewable resources. Let us begin now to conserve pest susceptibility to these tactics so that they remain viable tactics for pest management tomorrow.

In his presentation, Dr. Teodoro Stadler (Lab. de Parasitologia y Toxicologia, MACN-CONICET, Argentina) stressed the need for South American researchers and crop managers to take the initiative, pursue international collaborative projects, and to better communicate/share their findings, observations and problems with resistant pests and pest management with other South American researchers. These sentiments were repeated frequently among workshop participants and instructors. We were encouraged by the positive interactions between workshop participants and hope that several collaborative projects were indeed initiated. We remind you that the Resistant Pest Management Newsletter can serve as an important source of communication between researchers in South America as well as the rest of the world and we encourage you to submit articles dealing with pest resistance and resistance management. These articles may be in the form of resistant pest status updates, preliminary research findings, resistance management programs, research summaries, announcements for upcoming meetings or symposia, bibliographies, etc.

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IRAC US Meeting Minutes

The third meeting of the year was held at the ACPA headquarters in Washington, D.C. and at the Marriott in Crystal City, Virginia on October 4-5, 1994.

1. American Crop Protection Association (ACPA) - Ray McAllister, Director of Regulatory Affairs, ACPA, provided an overview of their organization and their relationship with the EPA. He indicated that ACPA and IRAC can work together in communication of information. ACPA is very strong in this area and will be able to assist in developing a communication link with the EPA.

2. WRCC-60 - David Heckel/Clemson provided an update of WRCC-60. The committee received a 3 year renewal status. WRCC-60 is sponsoring a symposium at the ESA honoring Bill Plapp, who will be retiring from Texas A & M University. The symposium is entitled "Biochemical Mechanisms of Resistance." WRCC-60 established a "Communications Committee" to address the publication of the Resistance Management Newsletter as well as other issues. The Resistance Pest Management Newsletter is very short on funding since USDA, a former contributor, will no longer be contributing to the cost of publication. IRAC US has been asked to provide $2,500 in emergency funding for assistance in continuation of the newsletter. It was unanimously agreed by the committee that this funding be provided in 1994. In the future, IRAC Central will be increasing their funding for its publication and IRAC US will contribute articles, and help where they can, but not provide funding.

3. Resistance Management Symposium - Considerable discussion was held regarding the subject symposium. In general, it was foreseen that such a symposium would not "tie in" with the American Chemical Society's conference entitled "Molecular Genetics and Ecology of Pesticide Resistance" scheduled to be held in Big Sky, Montana in June 1995. Also, a "tie in" with WRCC-60's conference scheduled for 1996 was discussed. The scheduling dates for the latter conference were felt to be too late. It was decided that a smaller IRAC US sponsored symposium in 1995, targeted for internal customers such as management personnel and others, from agricultural chemical companies, would be appropriate for the spring of 1995 (April being considered).

Assignment: A committee was nominated consisting of Ian Watkinson/Gowan, Joe Hope/Rhone-Poulenc, John Long/Rohm & Haas and Don Allemann/CIBA. Their assignment is to prepare a draft program and select a meeting site. The draft program is to be presented at our next meeting so that it can be finalized.

4. Tank Mix vs. Rotations Symposium - No commitment was made regarding the establishment of a symposium on this subject. It was suggested that this subject would be part of discussions in other resistance subject related symposia.

5. IRAC US Poster - Gary Thompson/DowElanco obtained copies of information presented on an IRAC Central poster. Modification is necessary to suit IRAC US. Poster space reservations have been made for the ESA meeting and the Beltwide Cotton Conference.

6. Educational Opportunities - Frank Carter prepared an article which was published in Agro Times. This article provided general information on IRAC US and its functions. This information can serve as a basis for a message that we are trying to communicate regarding the functions of IRAC US. It was agreed that a fold-out pamphlet would be appropriate to help with this educational process. It was also suggested that a wall poster be developed, for use at distribution points. Cotton Incorporated and the Cotton Foundation have offered help in processing such educational materials. ACPA could also be approached.

Assignment: Frank Carter/Cotton Foundation and Gary Thompson/ DowElanco will put together a prototype of a pamphlet which will be presented at the next meeting.

7. National Alliance for Independent Crop Consultants (NAICC) will be holding a meeting prior to the Beltwide Cotton Conference.

Assignment: Chuck Staetz/FMC will approach NAICC regarding a short presentation on IRAC US. IRAC US members are encouraged to make a plea to local groups whenever the opportunity arises.

8. Pyrethroid Efficiency Group (PEG) - Effective immediately, PEG will be fully integrated into IRAC US.

9. Constitution - IRAC Central was very receptive to changing IRAC US cotton to IRAC US. The purpose is to broaden the organization to include crops other than cotton. A draft constitution has been prepared.

Assignment: IRAC members to review the draft constitution by next meeting so that any changes and a vote can be made at the next meeting.

10. 1994 Research Projects - It was agreed that a status report of the funded 1994 projects be presented to the committee by the principal investigator at the next meeting. Also, it was suggested that IRAC US members obtain a written status report for each project to review prior to the next meeting.

Assignment: Dick Pence/Merck will contact Graften-Cardwell regarding "Acaricide Resistance Management Trials in California Cotton." Joe Hope/Rhone Poulenc will contact Toscano regarding "Formulation of Management Strategies to Extend the Effectiveness of Chemicals Needed for Silver Leaf Whitefly Control." Gary Thompson/ DowElanco will contact Leonard regarding "Managing tarnished plant bugs with insecticides." Prior to our next IRAC US meeting, Dick Pence, Joe Hope and Gary Thompson will send out the written status reports directly to the IRAC US membership.

11. IRAC Central Meeting - Ian Watkinson/Gowan and Chuck Staetz/FMC will represent IRAC US at Brighton, U.K. It was suggested that a representative from IRAC US attend each IRAC Central meeting.

12. Sticky Cotton Action Team - IRAC US input was requested. Ian Watkinson/Gowan will represent IRAC US at this meeting.

13. Research Proposal Guidelines - Ben Rogers/Zeneca prepared guidelines for preparing and reviewing proposals. As an addendum to these guidelines, it was suggested that there needs to be a clear statement as to: the length of project (1 year or multiple years), what other funding has been received and/or asked for, and IRAC US's right to disseminate data collected by principal investigators. It was also suggested that a letter of understanding be prepared when a project is funded.

Assignment: Ben Rogers/Zeneca will revise the research proposal guidelines and develop a form for researchers to complete when submitting proposals. Frank Carter/Cotton Council will develop a 1-2 page general information sheet designed for those interested in submitting proposals.

14. Insect Management Workshop - A four hour workshop is scheduled for Thursday, 1:00-4:00 p.m., January 5, 1995, at the Beltwide Cotton Conference. Frank Carter/Cotton Council drafted a program which he presented at the meeting. The subject of resistance will be part of the presentations. Updates on recommendations will be provided.

Assignment: Frank Carter/Cotton Council will finalize the program. He will ask Ian Watkinson/Gowan to moderate the session and publicize IRAC US.

15. Minor Use Bill - Ray McAllister provided information regarding resistance management in a minor use bill currently under consideration in Congress.

16. EPA Meeting - A 1.5 hour meeting was scheduled with EPA personnel. Approximately thirty individuals from the EPA attended. The attendance list is attached.

Janet Anderson, Acting Director of Biopesticides and Pollution Prevention, gave a short presentation on EPA functions. She indicated that many of those who attended were part of the Pesticide Resistance Management Working Group. With regards to resistance management, the EPA is currently looking at the policies of Section 18's and 24 c's. Frank Carter/Cotton Council reiterated the importance of a policy change regarding Section 18's since current policy does not allow for emergency exemptions for resistance management in cases where only one mode of action is available for control. Janet Anderson suggested that industry needs to take a pro-active approach about resistance management plans because extension needs to be better educated. She also indicated that the EPA has a need for training in resistance management.

Gary Thompson/DowElanco provided a general presentation on resistance principles and an overview of IRAC US as a group and its functions. This was very well received and appropriate for the type of audience. The EPA asked to be sent a copy of the IRAC "Methods for Susceptibility Testing."

Assignments: Walt Mullins/Miles will draft a letter to Ray McAllister/ACPA with an attachment entitled "Proposal on Prevention of Resistance/Resistance Management for Evaluating Section 18 Requests." Ray McAllister is to attach this to a "thank-you" letter addressed to Janet Anderson at EPA. Additionally, Ray McAllister is to send a letter of invitation for an EPA representative to attend our next meeting. Ray McAllister is also requested to contact to EPA as a follow-up regarding a training seminar for EPA personnel.

Chuck Staetz/FMC will send a copy of the IRAC Methods for Susceptibility Testing to the IRAC US members. A copy will also be sent to Ray McAllister who in turn will forward these to the EPA.

17. Future Meeting - The next meeting will be held on January 4, 1995, from 1:00 - 6:00 p.m. in San Antonio. An announcement will be sent out regarding the meeting room.

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Insecticide Resistance Action Committee (IRAC)

The 24th meeting of IRAC Central was held at Brighton, UK, 20-21 November 1994 under the chair of Paul Leonard. IRAC Central has now been restructured so that if there are direct links between the various country organizations (i.e. Pakistan, Mexico, China, etc.) to the most relevant working group and thus to IRAC Central. It was felt that this would improve coordination and make a more efficient organization. The meeting was pleased to welcome representatives from IRAC US, now with permanent representation on IRAC Central.

1995 Resistance Survey

It was agreed that IRAC should conduct another global resistance survey. The previous resistance survey is now published in the "Pesticide Manual." This survey provides a clear view of areas of concern where IRAC needs to concentrate its efforts. The survey also provides an authoritative list of cases of control failure for use in use management strategies and by authorities. It is hoped that the survey will be available Q3 1995 and will then be published and circulated.

Resistance Pest Management

It was agreed to continue funding of this important and widely read publication from Michigan State University. Without IRACs continued financial support the newsletter could not continue to be published.

Animal Health Working Group

There appears to be no interest from the individual companies in maintaining an interest in an Animal Health group, despite the evident need for resistance management in this area.

Information Pack

An information pack on IRACs work, strategy and achievements is now available from the author.

Public Health and Vectors Working Group

An ambitious project has been initiated to investigate resistance management in Anopheline vectors in Mexico. The project involves a collaboration between academics, WHO, companies and CIP. The aim of the project is to monitor changes in the susceptibility of Anopheline mosquitoes when subjected to different management strategies. This will produce invaluable data on the effectiveness of different management strategies in a field situation. The study is partially funded by IRAC Central and individual companies using representatives of the different classes of insecticide rather than specific products thus ensuring that the project generates principles rather than endorsement for specific products.

Field Crops and Vegetables Working Group

The group has been involved in monitoring baseline susceptibility to Colorado Potato Beetle (*Leptinotarsa decemlineata*) in Poland. In order to standardize on methods used, IRAC method no. 7 was used with cypermethrin, chlorfenvinphos and bensultap. Results indicate that there was a variation in response to cypermethrin and chlorfenvinphos which could indicate change in susceptibility. IRAC will continue to fund this work for a further 2 years.

Following a previous study on *Plutella xylostella* a resistance management strategy has been defined for this important pest. In order to help in the implementation of this strategy, the 3rd Diamond Back Moth workshop in Taiwan will be sponsored with $3000.00.

Cotton Working Group

China: In 24 locations in China IRAC method no. 7 has been used to monitor Heliothis armigera. The final reports are not yet available but IRAC Central continues to support the aims and objectives of this important work.

Pakistan: Monitoring of Heliothis armigera and whitefly has been extensively conducted and the final reports on this work are expected.

Baseline data on susceptible strains of Heliothis armigera and H. virescens will be made in a sponsored study by Dr. McCaffery, Reading, UK. This data will provide comparison with other studies on these species around the world and allow comparison and evaluation of susceptibility.

Fruit Crop Working Group

The group presented updated versions of its resistance management strategies for spider mites and an analysis of the problems in devising a resistance management guideline for *Myzus persicae* at the Brighton conference.

The sponsored study to evaluate the cross resistance potential of the 4 new METI acarcides (fenazaquin, tebufenpyrad, fenpyroximate and pyridaben) at Rothamsted has evaluated microimmersion, glass and plastic cell methods as practical methods to generate reliable dose response curves. Labeling of the 4 miticides in Europe has been agreed in principle to include a statement of only one application per crop per season and to avoid rotation and mixture with other METI acaricides. This initiative is prior to any reports of resistance with this class of acaricides and represents an important model for the future.

The group has almost completed resistance management guidelines for Aonidiella aurantil and Psylla. The latter will be published at the IPPC, Hague, Netherlands, July.

The next meeting of IRAC Central will be in April 1995, Copenhagen. If you have any questions or comments on the above, please address them to the author.

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IRAC US Meeting Minutes

The first meeting of the year was held on January 4, 1995, at the Hilton Inn in San Antonio Texas. Gary Thompson, DowElanco moderated the discussion on the following items:

1. IRAC Central Update - Ian Watkinson/Gowan provided an update of the IRAC central meeting he attended in Brighton, U.K. Issues directly related to IRAC US include: acceptance of the change from IRAC-Cotton-US to IRAC US, official closure of PEG, and that the IRAC logo has been developed.

Assignment: Ian Watkinson will contact IRAC Central regarding the logo artwork (proof) so that we can start using it in our future educational/promotional items.

2. Public Relations - Julie DeYoung/Fleishman-HIllard, a private public relations agency, provided an outline of a number of items with the following objectives for IRAC-US:

- o drive implementation of management principles to the grower level and,

- to increase awareness of IRAC US.

The main communication strategies would be: to provide information so others can take the message to growers, to develop versatile communications tools, and to capitalize on the positive nature of IRAC US work.

The target audience would be: primary - production influencers (extension and consultants) and, secondary - cotton growers. Fleishman-Hillard started working with IRAC Central approximately 6 months ago. "Making It Happen" was prepared thus far by IRAC Central.

Assignment: A sub-committee was formed consisting of Ian Watkinson/Gowan, Dick Pence/Merck, Gary Thompson/DowElanco, Pat O'Leary/Cotton Inc., and Frank Carter/National Cotton Council to study the proposal presented by Julie DeYoung/Fleishman-Hillard. Frank Carter/National Cotton Council has collected much of the information necessary for development of a leaflet which will be discussed by the sub-committee. A recommendation will be presented by the sub-committee, at the March 1995 meeting regarding the area of public relations.

3. Research Proposal Guidelines - Gary Thompson/DowElanco prepared a hand-out entitled "Guidelines for Soliciting IRAC US Support" which is a synopsis of the draft guidelines prepared by Ben Rogers/Zeneca presented at the October 1994 meeting.

Assignment: Frank Carter/National Cotton Council will prepare a "flow chart" and "check list" for evaluation of research proposals. This will be presented at the March 1995 meeting.

4. Constitution - Minor changes were made to the draft constitution. A unanimous vote allowed for its ratification.

5. American Chemical Society Conference - A conference will be held in June in Big Sky, Montana. Our participation and support was requested. A unanimous vote allowed for a $2,500 contribution. Also, it was agreed that the IRAC US poster be displayed at the meeting. There is opportunity for a presentation on the program. No commitments have been made by anybody.

Assignments: Gary Thompson/ DowElanco will contact Tom Brown/Clemson regarding arrangements for the poster display and further directions on type of speaker/ content needed. A recommendation for a speaker will be made at the March 1995 meeting.

6. 1994 Research Projects - Roger Leonard/ Louisiana State University provided an update on his project entitled "Managing Tarnished Plant Bug on Cotton with Insecticides". As part of the Beltwide Cotton Conference Program, presentations will be made on the following subjects by the principal investigators/co-investigators: "Acaricide Resistance Management Trials in California Cotton" (Graften-Cardwell), and "Formulation of Management Strategies to Extend the Effectiveness of Chemicals Needed for Silver Leaf Whitefly Control" (Toscano).

Assignment: Joe Hope/Rhone-Poulenc will obtain a report from Toscano and Dick Pence will obtain a report from Graften-Cardwell by the March 1995 meeting.

7. New Research Proposals - Dave Marsden/ DuPont handed out a copy of a proposal received from Betsy Beers/Washington State University entitled "Regional Resistance Management of Spider Mites on Apple and Pear". Considerable discussion resulted among the group.

Assignment: Dave Marsden/DuPont will contact Betsy Beers regarding several suggested comments and changes. A revised proposal will be sent to the committee members for review prior to the March 1995 meeting.

8. Desert Meetings - Ian Watkinson/Gowan summarized information obtained at two meetings (Phoenix 10/20/94 and Yuma 11/16/94). These meetings involved development of management programs (including resistance management) for the minimization of "sticky cotton."

9. Visitors - Doug Sutherland/EPA presented a general update of his involvement with resistance management and the EPA in general. He indicated that the EPA is much more "open" to communication than they have been in the past.

Randy Deaton/Monsanto gave a short statement of his involvement with the BT Working Group. This group also funds research and educational efforts. He suggested that we should consider combining resources particularly in the educational area.

10. Future Meeting - The next meeting will be held on March 8 in Charleston, SC immediately after the Southeastern Branch ESA meeting. An Announcement will be sent out regarding the meeting room and hotel location.

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IRAC US Meeting Minutes

The second meeting of the year was held on March 8, 1995 at the Sheraton Inn in Charleston, SC. Gary Thompson/DowElanco moderated the discussion on the following items:

1. Minutes - John Lublinkhof/AgrEvo read the meeting minutes from the January 4 meeting held in San Antonio, TX. These were accepted as read.

2. Educational and Public Relations Proposal - A proposal was prepared by Fleishman-Hillard using the input provided by the IRAC US sub-committee (Ian Watkinson/Gowan, Dick Pence/Merck, Gary Thompson/ DowElanco, Pat O'Leary/Cotton Inc., and Frank Carter/National Cotton Council. In principle, there was unanimous agreement that the educational/public relations effort is necessary. However, the budget proposed assumes a $20,500 match from IRAC-Central. This is to be discussed at the IRAC Central meeting to be held in early April. The budget for the remainder of the proposal still exceeds our capacity. IRAC US unanimously agreed to budget $20,000 towards this effort. Additionally, Cotton Inc. has generously agreed to contribute $5,000 towards this educational effort. Frank Carter/National Cotton Council indicated that they could possibly provide $2,500-5,000 additional support. The following were established as priorities: brochures, funding solicitation, and posters.

A review process was also discussed. It was agreed that the sub-committee listed above would work closely with Fleishman-Hillard in preparing draft and the coordination activities associated with this process. It was also agreed that the following researchers be asked to review the drafts: Mark Whalon/Michigan State University, Tom Fuchs/Texas A & M University, Ron Smith/Auburn University, Gary Herzog/University of Georgia, Jerry Graves/Louisiana State University, James Ottea/Louisiana State University, Betsy Beers/Washington State University, Brian Croft/Oregon State University, Beth Graften-Cardwell/University of California and Nick Toscano/University of California. The whole IRAC US committee would also need to review the drafts.

Assignments: Frank Carter/National Cotton Council will determine funding availability from NCC towards the development of educational materials. Ian Watkinson/Gowan will contact ACPA regarding contribution of funds. Gary Thompson/DowElanco will contact Fleishman-Hillard and IRAC Central regarding the proposal and decisions made at this meeting. He will also discuss funding from the BT Working Group through IRAC Central. The remaining IRAC US members are asked to collect key papers/reprints which could be endorsed as part of an educational package and to check with their own companies regarding distribution and quantities to be printed. Gary Thompson will also invite Susan McIntosh/Novo Laboratories, Chairman of the BT Working Group, to attend our next meeting.

3. Research Proposals - Three research proposals were received. The following table lists the level of funding agreed upon unanimously by the committee members. Table 1

Research Proposal	Amount Requested	Action/Response
Validation of an Insecticide Resistance Management Strategy for *Heliothis virescens* in U.S. Cotton: Ottea and Leonard, Louisiana State University	$8,500.00	8500.00 approved
Strategies to Extend the Effectiveness of Chemicals Needed for Silverleaf Whitefly Control: Toscano, University of California	$10,000.00	5000.00 approved to help support program pending modification of proposal
Regional Resistance Management of Spider Mites on Apple and Pear: Beer et al., Washington State University	$26,266.00	$8,00.00 approved to help support program pending modification of proposal

Assignment: James Whitehead/ American Cyanamid will contact James Ohea/Louisiana State University, Joe Hope/Rhone Poulenc will contact Nick Toscano/University of California and David Marsden/ DuPont will contact Betsy Beers/Washington State University regarding the decisions on funding.

4. Procedure for Processing Research Grants - Frank Carter/National Cotton Council drafted "Guidelines for Submission of Proposals to IRAC US" changes were made and were noted.

It was agreed that all research proposals are needed in the hands of an IRAC US committee member by November 15, who in turn needs to distribute it to the other members. Ideally, some proposals will be received prior to our fall meeting so that a preliminary review/ discussion can occur at that time. At the Beltwide Cotton Conference (January), a final decision will be made regarding the proposals and funding. Researchers will be notified by January 15.

5. IRAC Logo - Ian Watkinson/Gowan obtained a copy of the IRAC Central Logo which can be used by IRAC US. Assignment: Ian Watkinson/Gowan will contact IRAC Central about obtaining an electronic version. He will also contact the ACPA (American Crop Protection Association) regarding the logo and will check into copyrighting the logo.

6. Outreach Training - Joe Hope/Rhone Poulenc, Don Allemann/CIBA and John Long/Rohm & Haas attended the NAICC (National Alliance for Independent Crop Consultants) Meeting and Ian Watkinson/Gowan visited with committee members. NAICC welcomed IRAC US participation in their January 1996 meeting to be held in Orlando, FL. The committee unanimously agreed to develop a list of topics for approximately 3 hours on the program. The following are suggested topics and speakers for this section of the program:

- BT Cotton - Randy Luttrell/Mississippi State University or J.R. Bradley University of North Carolina and Report from BT Working Group.
- Colorado Potato Beetle, Diamondback Moth - Tony Shelton/Cornell
- IRAC - Worldwide Update/Monitoring - Ian Watkinson/Gowan
- Bollworm/budworm and plant bug - Roger Leonard/LSU
- Regulatory Labeling - Sharlene Matten/EPA
- Whitefly/Mites - Tim Dennehy/University of Arizona

Gary Thompson/DowElanco will present a paper and display a poster at the American Chemical Society Big Sky conference to be held in June, 1995. His topic will be "The Insecticide Resistance Action Committee: A Continuing Industry Initiative." The outline is as follows:

1. Introduction - Why industry is serious about managing resistance.
2. IRAC US History and Alignment to IRAC Central and ACPA
3. Function and Activities
4. Completed Projects - U.S.
5. Current Projects
6. Current Status of Resistance Around the World
7. Future Projects - IRAC Central and IRAC US 5 year plan

Roger Leonard/Louisiana State University suggested that IRAC US participate in training consultants in Louisiana. However, it was agreed that we are not ready to pursue this activity this month. It was agreed that such training will be part of our overall educational effort which we are currently developing through Fleishman-Hillard.

Assignments: Ian Watkinson/Gowan will contact Charles Mellinger regarding the NAICC meeting program. Dick Pence/Merck and Ian Watkinson/Gowan will review Gary Thompson's/DowElanco presentation prior to his presentation at the ACS Big Sky Conference.

7. EPA Involvement in Resistance Issues - Sharlene Matten/EPA had questions for IRAC US regarding their involvement in resistance issues. The committee, in general, was reluctant to have EPA make decisions on resistance management but favored open discussion on issues. There was concern that discussions could lead to regulation or types of recommendations that may not be acceptable. There was a strong recommendation that an EPA representative attend our meetings (at least once per year). It was proposed that Sharlene Matten/EPA be invited to our next meeting at IRAC US expense, if necessary.

Assignment: Gary Thompson/ DowElanco will contact Sharlene Matten/EPA regarding attending our next IRAC US meeting.

8. Next Meeting - The next meeting will be held on September 7, in Indianapolis. An announcement will be sent out regarding the meeting room and hotel location.

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Announcements

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